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CONTENTS

Durability of Foundry Sands and Properties of Deteriorated Foundry Sands 1

The Use of Sodium Silicate in Steel Casting Molds and Cores 7

Intergranular Fracture in Steel Castings (Parts I and II) 10

New Project on Sand 16

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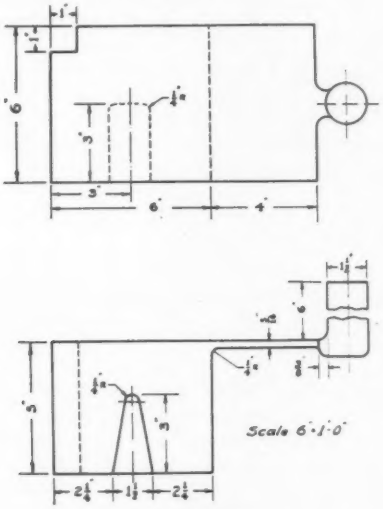
DURABILITY OF FOUNDRY SANDS AND PROPERTIES OF DETERIORATED FOUNDRY SANDS

*by D. K. Faurschou**

This report presents the results of an investigation of both the comparative durability or useful life of foundry facing sands and of the characteristics and properties of sand mixes made from new and used sands. The program was undertaken with two objectives: first, to determine whether or not any particular foundry sand may be used more often than other available sands, and second, to determine a reliable method of recognizing when used sand is no longer suitable for facing mixes for castings weighing under five hundred pounds.

Durability was determined by actually pouring sets of castings in a batch of sand which was bonded and rebonded until it deteriorated and produced scabs on the castings. The casting, shown in Figure 1, was developed by the S.F.S.A. It was known to be susceptible to scabbing on the plate.



a—Test casting

Figure 1—SFSA Test Block use for repeated-pour durability tests

To detect deterioration of the used sand mixes, results were assessed from room temperature tests, elevated temperature tests, chemical analysis and microexamination.

Three sands were used in these tests. The selection was based upon data from a questionnaire survey of the sands used in member foundries. The test sands are the most frequently used sands near the most common grain fineness (about A.F.S. 60) with variations in grain shape, screen distribution and clay content. These sands were supplied by member foundries from current stocks.

Procedures and Equipment

A four hundred and fifty pound induction melt of steel was made for each set of castings. A set of castings consisted of four, three or two castings depending upon how much sand remained from the original batch. The excess steel served to maintain the pouring temperature, of the test castings, almost constant. The heats were poured at 2950 degrees F. from a teapot ladle of five hundred pounds capacity.

With one exception, the analysis range for the steel was .20 to .30 percent carbon, .50 to .70 percent manganese, .20 to .40 percent silicon, .020 to .040 percent sulphur and .020 to .030 percent phosphorus. The exception occurred in series 5 in which some of the silicons were lower than 0.20 percent and consequently the castings from the third use were gassy.

A seven hundred pound batch of sand was used for each series of durability tests. Each scab test casting was cast into a mold containing about one hundred and fifty pounds of sand mix. The castings were allowed to remain in the molds for one hour before shakeout; then, the used sand and any excess sand mix were blended and spread on the foundry floor to cool before riddling. About twenty-five pounds, equivalent to three and one-half percent of the batch of sand, was lost with each test use. After ten uses about four hundred and fifty pounds of sand mix, or enough to mold three castings, was left.

The only intentional variables in the durability tests were the use of different sands and variations of the mold hardness of the drag surface of the scab plate. These variables for each series are detailed in Table 1.

TABLE 1—Intentional Variables in the Durability Series

Durability Series No.	Type of Sand.	Mold Hardness
1	Ottawa A.F.S. 58	65
2	Ottawa A.F.S. 58	75
3	Minneapolis A.F.S. 61	75
4	New Jersey A.F.S. 66	75
5	Ottawa A.F.S. 54	90
6	Ottawa A.F.S. 54	90
7	New Jersey A.F.S. 66	90

All molding was performed on a jolt-squeeze machine. Variations in the mold hardness of the drag surface of the scab plate, immediately after

* Steel Castings Institute of Canada.

molding, were obtained as follows. For a hardness of 65, a layer of sand was hand rammed, the mold was filled, jolted 10 times and squeezed. For a hardness of 75 all of the sand was hand rammed in layers, jolted 35 times and squeezed. For a hardness of 90 the green compressive strength was increased and all of the sand was hand rammed, jolted 35 times and squeezed.

The new sand of series 1 to 4 was bonded with 4 percent Volclay, 1 percent Casco (gelatinized corn flour) and 3 percent moisture to give a green compressive strength of 6.5 to 7.0 psi. One hundred pound portions of sand mix were mulled dry for one minute and wet for four minutes in a Simpson mixer having one muller and one scraper. For series 5 and 6 mixes the new sand was bonded with 5 percent Volclay, 1 percent Casco and 3.15 percent moisture, to give a green compressive strength of 8.0 to 9.0 psi. This strong mix was mulled wet for 8 minutes.

Series 7 was bonded similarly to series 5 and 6 but was wet-mulled, in 175 pound portions, for five minutes. All used sand was rebonded with Volclay and Casco in a 4 to 1 ratio to maintain the green compressive strength.

Normal tests at room temperature and some special tests such as pH were performed with samples from the sand mixes which were used for the drag of two of every set of castings. As required, extra samples were taken for special tests such as microexamination, chemical analysis and tests at high temperatures.

A Zeiss stereomicroscope was used for visual microexamination and also for three dimensional photographic records.

A Dietert Thermolab No. 785 and Sinter meter were used for tests at high temperatures. For the simultaneous stress—deformation tests on the Thermolab, a Robot camera was used to record data.

Durability Tests

The characteristics of grain fineness, grain shape, screen distribution and clay content of the test sands, are shown in Table 2.

Durability results, as evidenced by the occurrence of small and of large scabs, plus other pertinent data are summarized in Table 3.

It may be observed from Table 3 that without exception large scabs first occurred on the 6th, 7th or 8th use. In series 1 to 4 inclusive, which were molded to a relatively low mold hardness, the small scabs first occurred on the 6th or 7th use. In series 5, 6 and 7, which were molded to a high hardness of 90, small scabs had a tendency to occur, in a random manner, earlier in the series. At the high hardness level small scabs occurred as early as the 2nd and 3rd use.

TABLE 2—Characteristics of Test Sands

District	A.F.S. G.F.N.	Grain Shape	Screen Distribution	A.F.S. Clay	U. S. SIEVE TEST % RETAINED ON SCREEN NUMBER								
					30	40	50	70	100	140	200	270	PAN
Ottawa	58.4	Round	3 screen	0	—	.3	16.8	44.5	31.0	6.5	.8	tr	tr
Ottawa	54.3	Round	3 screen	0	—	4.4	28.6	37.0	24.8	4.4	.2	.5	tr
Minneapolis	61.3	Round	4 screen	2.0	—	2.8	32.6	27.2	18.6	11.2	4.7	.5	.3
New Jersey	66.4	Semi-angular	4 screen	0	.2	4.8	15.8	27.8	31.7	14.0	4.8	.6	.2

TABLE 3—Durability Results and Test Data

Series No.	Type of Sand	A.F.S. Grain Fineness	Mold Hardness	Occurrence of Scabs (Use)		Number of Uses	Number of Castings For 9 Uses	Total Volclay For 9 Uses (%)
				Small Scabs*	Large Drag Scabs			
1	Ottawa	58	65	6,8	8, 9, 10	10	29	6.87
2	Ottawa	58	75	6,7	8, 10	15	29	7.25
3	Minneapolis	61	75	7	6, 9, 10	10	30	6.25
4	New Jersey	66	75	6,8	8, 9	9	35	7.75
5	Ottawa	54	90	2,3,4,5,6,7,	6, 8, 10	10	32	9.375
6	Ottawa	54	90	6,7,8	8, 9	10	33	9.62
7	New Jersey	66	90	3,4,7,9	6, 8, 10	10	33	8.85

* The castings in the third-use (3) were gassy.

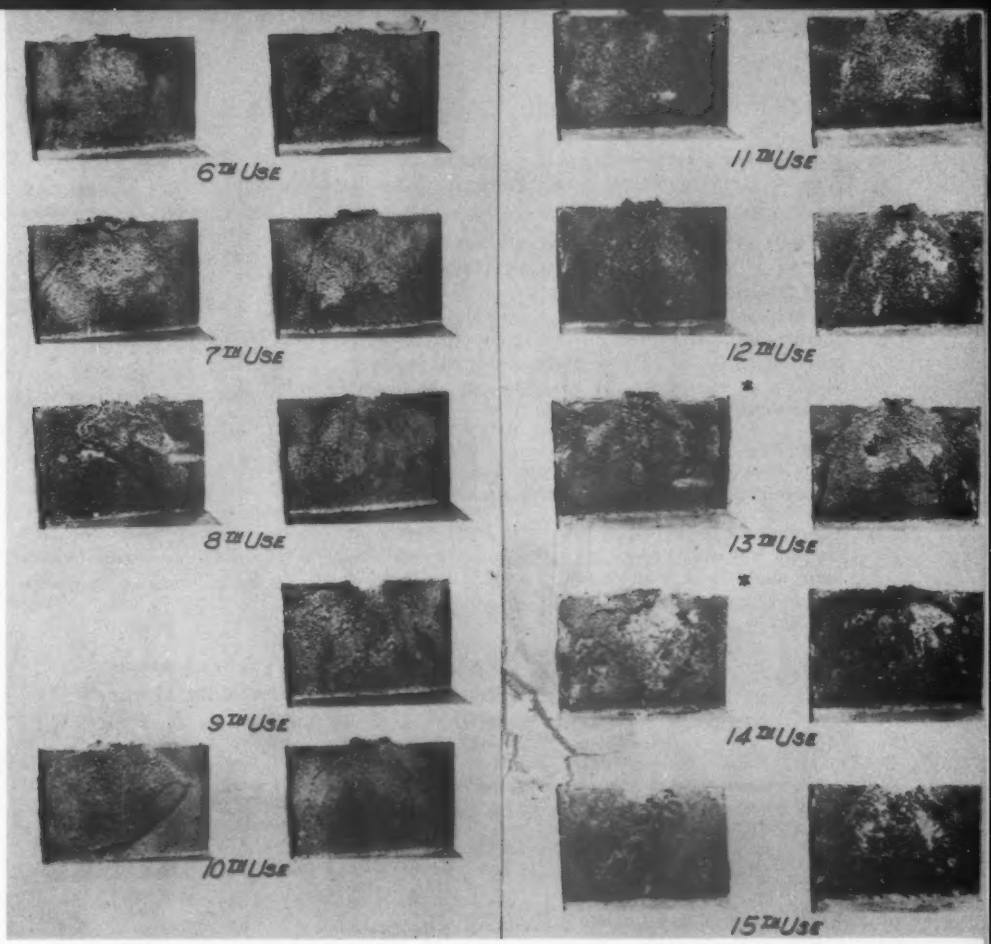


Figure 2—Representative drag surfaces of scab plates from the 6th to the 15th use of Series 2, mold hardness 75, pouring temperature 2950 degrees F, AFS Grain Fineness 58

The difference between small and large drag scabs was always obvious. This is apparent in Figure 2 which shows the drag surface of representative scab plates from the 6th to the 15th use of series 2. Large drag scabs are shown on the 8th and 10th use. Small drag scabs are shown on the 6th and 7th use. The plates were only lightly sand blasted. Heavier commercial shot blasting will remove the mottling and considerably improve the surface appearance.

It has been noted that the initial use on which large drag scabs occurred was reasonably consistent. However, Table 3 and Fig. 2 show that after initial bad scabbing the deteriorated sand does not always produce scabs upon subsequent reuse. In series 2 consistently bad scabbing did not occur until after 12 uses.

Sand Properties at Room Temperature

Absolutely no correlation could be detected between any room temperature property and the susceptibility of a used sand mix to cause scabbing. This is apparent from Table 4 where, for an example, the individual properties of each use of series 2 are recorded. Observe that the properties of the sand mixes do not reflect the deterioration which was evident in Fig. 2. The variations from heat to heat in Table 4 are representative of all series.

The properties of the sand mixes varied from series to series depending upon the type of sand, the moisture content, and the bond additions. The average properties for all series may be compared in Table 5.

The sieve analysis is affected to only a small extent by repeated use of the sand. This is shown in Fig. 3.

The used sand differs from the new sand by having a greater proportion both of coarse grains (plus 40 and plus 50 mesh) and of fine grains (plus 200, plus 270 and Pan) with a corresponding decrease in the proportion of intermediate grains (plus 70, plus 100 and plus 140 mesh). After 10 uses the A.F.S. grain fineness number increased from 58.4 to 60.5.

Sand Properties at Elevated Temperatures

New and used sands were tested for hot compressive strength, resistance to thermal shock, unaccommodated expansion, sintering point and gas evolution. The results for hot compressive strength and thermal stability are interesting as they do reveal some differences between new and used sands. These differences apparently correlate with susceptibility to scabbing under the test conditions.

Hot compressive strength . . . A chart of hot compressive strength versus temperature is shown in Fig. 4.

The maximum strength occurs at close to 1675 degrees F. The hot compressive strength of the used sand increases to a maximum level after about six uses and remains at this maximum level with further use. The observed increase in the susceptibility of the sand to scab after about six uses may possibly be related to the relatively high hot compressive strengths.

Resistance to thermal shock . . . Thermal instability was evidenced by behaviour under test of the hot compression and of the sintering point specimens.

Resistance to thermal shock of the hot compression samples was observed to be poor after the sand had been used about four times. At 1750 degrees F slight cracks developed slowly in the used sand

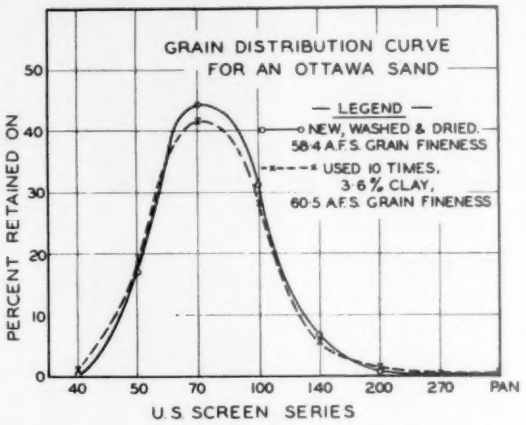


Figure 3—Grain size distribution for new and old sand after 10 uses

TABLE 4—Properties of Sand Mixes Pouring Temperatures, and Mold Hardness for Each Use in Series 2 (Ottawa A. F. S. 58)

Use No.	Moisture %	Permeability	Gr. Comp. psi	Gr. Shear psi	Gr. Tensile oz/sq. in.	Gr. Deformation*	Dry Bond psi	pH		Pouring Temp. (°F)	Hardness of Scab Plate	
								Tap Water	Dist'd Water		Cope	Drag
1	3.0	167	7.1	—	9.8	31.4	47	8.5	8.2	2965	76	74
2	2.6	167	5.6	—	10.2	28.5	90	8.4	7.6	2955	74	74
3	2.9	170	5.0	—	9.1	—	108	7.7	7.6	2965	76	73
4	2.5	178	6.4	—	14.3	—	82	7.8	7.6	2955	76	77
5	2.5	178	6.6	2.1	14.0	—	82	8.1	7.6	2965	78	74
6	2.9	162	5.9	—	12.3	—	124	7.4	7.5	2965	76	74
7	2.6	178	6.4	1.8	14.0	—	68	7.7	7.7	2950	76	76
8	2.7	167	7.4	—	13.8	—	62	7.6	7.4	2950	75	75
9	2.7	167	7.0	—	15.0	—	76	7.6	7.6	2950	75	73
10	2.9	170	6.7	2.2	13.2	—	90	7.8	7.8	2965	77	77
11	2.8	173	7.4	2.1	14.8	—	75	—	—	2965	77	76
12	3.25	156	7.0	2.0	14.0	—	135	—	—	2950	73	75
13	2.7	167	7.8	2.0	15.1	—	80	—	—	2955	77	76
14	2.95	158	5.9	1.65	10.8	—	117	—	—	2950	75	75
15	2.6	178	7.8	2.25	15.1	—	57	—	—	2950	75	75

* Data is lacking for Green Deformation because the necessary equipment was returned to the manufacturer for repairs.

TABLE 5—Average Sand Mix Properties for all Series

Series Number	Moisture percent	Permeability No.	Gr. Comp. psi	Gr. Shear psi	Gr. Ten. oz/sq. in.	Dry Bond psi
1	2.77	158	6.4	—	13.6	96
2	2.77	159	7.1	2.0	13.1	86
3	2.75	117	7.1	2.2	15.8	119
4	3.1	109	6.6	1.95	11.2	95
5	3.13	219	8.3	2.75	—	—
6	3.16	241	8.6	—	28	69
7	3.5	138	8.1	—	23	88

specimens. As the temperature was increased cracks developed faster and more often. At 2500 degrees F cracking and spalling was almost immediate for sand used ten times. In contrast, cracks were seldom seen in the new sand specimens and at 2500 degrees F they were semiplastic.

The sintering tests at 2500 degrees F (measured optically) confirmed the poor thermal stability of used sands. When sintering tests were carried out on sands used more than four times, a mound of sand adhered to the ribbon and broke the specimen. For sands used four times or less, the specimen adhered to the ribbon but could be stripped cleanly without breaking and could be removed easily from the ribbon. When the temperature was increased to 2650 degrees F, cohesion, due to extensive sintering, was so great that the platinum ribbon may be stripped from both new and used sand without breaking the specimen.

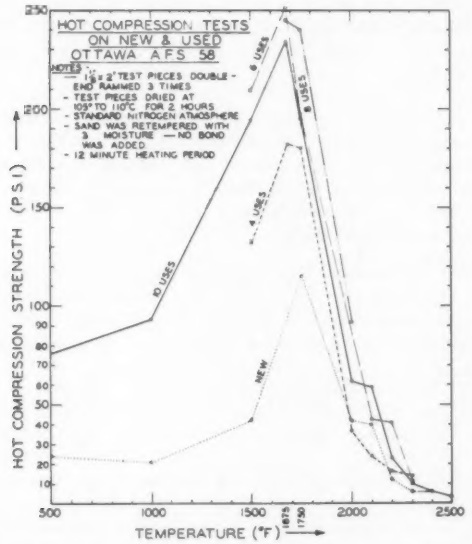

HOT COMPRESSION TESTS
ON NEW & USED
OTTAWA A.F.S. 58
NOTES:
- 1½ x 2" TEST PIECES DOUBLE-END RAMMED 3 TIMES
- TEST PIECES DRIED AT 105° TO 110°C FOR 2 HOURS
- STANDARD NITROGEN ATMOSPHERE
- SAND WAS RETEMPERED WITH 3 MOISTURE — NO BOND WAS ADDED
- 12 MINUTE HEATING PERIOD
HOT COMPRESSION STRENGTH (P.S.I.)
TEMPERATURE (°F)
15 USES
8 USES
4 USES
NEW
1675
1750

Figure 4—Hot compressive strength of new and used sands

The poor resistance of the sands to thermal shock, after four uses, may well have contributed to their observed susceptibility to scabbing. This conclusion is in accord with the generally accepted theory that a crack or spall in the mold surface may initiate a scab defect.

Unaccommodated expansion . . . The 8-J Committee of the A.F.S. has spent several years on fundamental high temperature research and has found some correlation of unaccommodated expansion with susceptibility to scabbing. The theory supporting their results is that when sand expands more than it can deform a crack must form in the mold surface and may promote a scab. Fig. 5, compares graphs of expansion and deformation for the used sand, which was very susceptible to scabbing, with graphs of expansion and deformation of the same sand while new. The enclosed area between the expansion and deformation curves represents unaccommodated expansion.

The 8-J A.F.S. sand mixes are such that as the enclosed area increases the tendency for their test castings to scab also increases. Unfortunately, according to these results (Fig. 5) the Ottawa sand mix has not deteriorated with use.

Sintering point . . . The sintering point of test sand mixes, as detected by microscopic observation of incipient fusion, was not significantly reduced.

Gas evolution . . . The evolution of gas at 2500 degrees F was not found to be greater from used sand than from new sand mixes.

Coatings on Used Sands

Composition . . . Chemically, the only constituents which altered in quantity so a sand mix was reused were carbon and iron. The carbon and iron build-up until the fourth use and then remain almost constant at 0.4 and 0.55 percent respectively. These

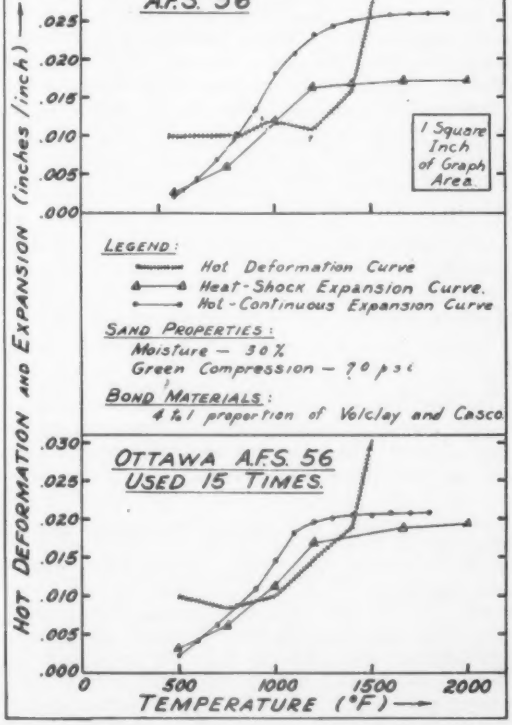


Figure 5—Graphs showing unaccommodated expansion of an Ottawa sand mix both new and after 15 uses, very susceptible to scabbing

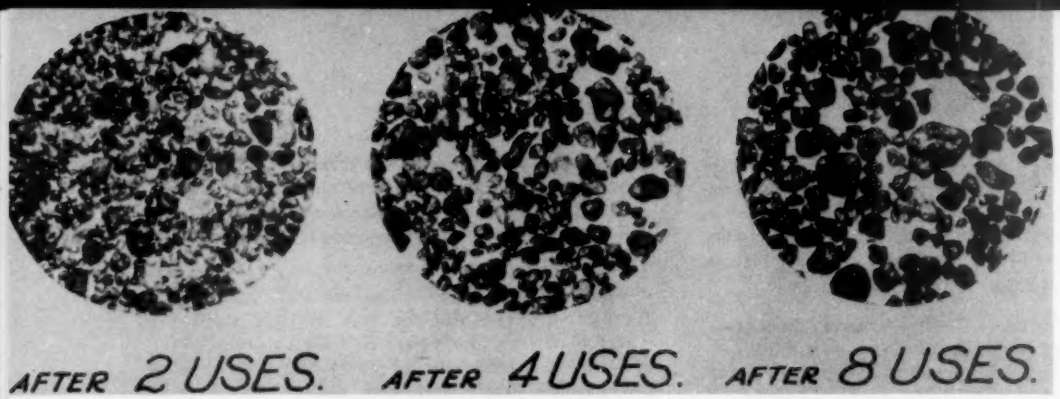


Figure 6—Ottawa sand, series 2 (25X)

minor overall chemical changes, in the light of the very limited durability which was observed, and considering the fact that in industry reclaimed sand can replace new sand, indicate that deterioration occurred in the bond and not in the sand.

An attempt was made to determine how the deteriorated bond differed from new bond. The very adherent coatings were separated from the used sand grains. One method of separation, which was slow but simple was to screen the used sands and magnetically remove the separated shell-like fragments of coatings from the material retained on the fine screens.

The shells are so magnetic that the used sand grains with well developed coatings may be lifted with a magnet. The separation method used for larger samples consisted of washing the sand well to remove live colloidal bond, wet-mulling the sand to remove the very adherent coatings, wet screening the sand from the pulp of pulverized coatings, filtering the pulp, drying the filtrate and magnetically concentrating to eliminate fine sand particles.

Data in Table 6 shows chemical analyses, colloidal activity in water, and magnetic susceptibility for separated coatings, Volclay (western bentonite), and casting peel.

The coatings were separated by the filtering process described in the text. The +200 and −200 mesh fractions of casting peel were obtained after partly crushing a sample of peel with a mortar and pestle.

Volclay is the only source of Al_2O_3 for the coatings, so the analyses in Table 6 indicate that the coatings are about 75 percent bentonite.

The bentonite in these very adherent coatings is dead (burned-out). It was non-colloidal in water and possesses almost no bonding power.

It seems possible that some of the iron in the coatings was contributed by crushed casting peel which is the only apparent source of ferrous iron for the bond. The reasoning is as follows: Volclay is not magnetic but the coatings and peel are magnetic. The coatings are magnetic and contain about 4.6 percent iron, mostly ferrous, while the non-magnetic bentonite only contains about 2.7 percent iron, mostly ferric. Finally, the peel is magnetic and contains over 11 percent iron, mostly ferrous. The magnetic constituent in peel is known to be fayalite ($Fe_2\ SiO_4$) formed by the reaction of ferrous oxide with silica.

No experiments were made to determine whether or not additions of dead bentonite or fayalite will hasten deterioration. It might be interesting to bond a batch of sand, then burn out the bond at 1000 degrees F, then rebond the sand mix and run a series of durability tests.

No experiments were made to investigate whether or not durability of a sand mix may be prolonged or shortened by additions of other materials such as wood flour, silica flour and core oils.

Microscopic examination of used sands . . . The progressive formation of a cokey coating or shell on sand grains was observed after each use through a stereoscopic microscope. Sands from successive uses were readily identified or distinguished from one another up to ten uses after which the appearance of the coatings changed more slowly. Stereoscopic photomicrographs are necessary to properly record the details of the appearance of the coatings. Ordinary photomicrographs as in Fig. 6 are most unsatisfactory. However, they do give some indication of the progressive build-up of a coating.

(continued on page 15)

TABLE 6—Various Properties and Chemical Analysis of the Substances Shown

Substance	COMPOSITION (%)							
	C	Iron Ferrous	Ferric	Total	SiO_2	Al_2O_3	Colloidal in Water	Magnetic
Coatings	5.80	4.06	.54	4.60	58.36	14.41	No	Yes
Volclay	.16	.20	2.50	2.70	60.60	19.84	Yes	No
Casting Peel		11.52	1.60	13.12			No	Yes
Peel + 200 mesh	.01	10.3	.22	10.55	84.06	1.32	No	Yes
Peel − 200 mesh	.046	17.85	.55	18.40	72.16	2.19	No	Yes

THE USE OF SODIUM SILICATE IN STEEL CASTING MOLDS AND CORES

Literature Survey

*by Robert D. Fenity**

Sodium silicate, or "waterglass," has been used as a bonding agent in cores and molds for metal castings since 1882 in this country. The majority of the information available on these uses concerned the batching and fabrication of cores where relatively high strengths were desired. Particularly the foreign literature contained some information concerning the use of soluble silicates as a bonding agent for molds.

Background Information on Soluble Silicates

The materials generally referred to as soluble silicates are the reaction products of the oxides of sodium and potassium with silicon dioxide. Because of cost and availability factors, silicates of sodium are of the most interest commercially. These silicates are manufactured by fusion of silica sand with the alkali carbonate or the alkali sulfate at temperatures of 2200 to 2500 degrees F in an open hearth type of furnace.[1] The reaction product is a clear glass. Although the most common compositions produced contained SiO_2/Na_2O ratios of 3.3:1 or 2.1:1, ratios varying over the range of 1.6:1 to 3.75:1 are commercially available. These products can be purchased directly as fine powders ground by ball milling or as water-solutions.

The majority of commercial sodium silicate is sold either as solutions in water or as hydrated crystals. In either case, the molten silicate is generally drawn from the furnace directly into water. This treatment, known as "fritting", fractures the glass into a more readily soluable, friable, granular condition. The granule is then dissolved in hot water by stirring, sometimes under steam pressures of 90 to 100 pounds gage. Sodium silicate is also available in free flowing hydrated crystals which are more readily soluble in water than the previously described powdered glass. Economically, however, the liquid solutions are generally the more attractive except in cases of very large quantity use. There is marketed some fifteen varieties of vitreous and crystalline forms of sodium silicates and about thirty-three liquid products.

In general, two quantities are required to identify a specific sodium silicate solution. The first of these, mentioned above, is the SiO_2:Na_2O ratio usually expressed as a ratio of the weights of the two oxides. The second concerns the concentration of the solution and may be designated as a weight percent of solids, as the specific gravity or the density of the solution. Quite commonly the densisy is stated in the Baume′ scale. A conversion chart between degrees Baume′ and density in the C. G. S. system has been prepared[1]. As an approximate comparison 30° Be′ corresponds to a density of 1.26 grams/cc, 40° Be′ to 1.375 grams/cc, and 50° Be′ to 1.525 grams/cc.

Mold Making With Sodium Silicate

Little of the literature presents details concerning the types or concentration of sodium silicate used in the mold compositions. Acheson[2] employed a solution with a specific gravity of 1.10 without specifying the silica to soda ratio. Ikley[3] used a 40° Be′ solution. Many other authors did not specify what solution was used in their work[4-10]. Potocki[11] stated that the best solution had a specific gravity 1.35 and a SiO_2/Na_2O ratio of 2.82:1 while Wood[12] recommended the ratio of 3.25:1 while ratios as low as 2.5 have been indicated[13].

The sodium silicate binder for the fabrication of molds has been used alone and in conjunction with other organic and inorganic binders and modifiers in molding sands. The literature recommended the use of from ½ to 18 percent by weight of silicate solution, the preferred range appeared to be 4 to 8 percent. Numerous modifying additions have been used. One of perhaps primary importance was the incorporation of 1.0 to 3.5 percent of bentonite [3] [19] which served to increase the green strength of the mold material. One-half to one percent of asphalt, pitch, dextrines, molasses or sugar have been added to "provide more plasticity to the bond and to lower the retained strength of the sand mass," and to improve shakeout. Hydraulic lime has been used to combine with excess water [6] and ZnO additions have been recommended to stabilize the sodium silicate against pick up of moisture from the atmosphere [12].

No deviation from standard mixing practice appeared to be necessary with the sodium silicate-sand mold batch except that excessive mixing which might raise the temperature nor the use of hot sand could be allowed due to premature setting of the batch [19].

Molds were formed from the batch in the usual manner. Mechanical molding on a "jolt" machine has been used. The silicate bonded sand has also been used as facing sand only. The major problem in molding appeared, from the literature, to be that of sticking of the mold material to the pattern and flask. It was recommended that patterns have generous tapers and be free of dents or undercuts. Parting agents on the patterns such as graphite suspended in kerosene, rubber base paint and nitrocellulose lac-

* Horizons Incorporated, Cleveland, Ohio.

quer have been used successfully. Damaged places in the mold could be repaired by brushing the broken surface with waterglass and patching with silicate bonded sand.

The curing or setting of the mold formed with a sodium silicate bond has been carried out in a variety of ways. Primarily these methods involved drying of the silicate or reaction with an acid. Storage in air for several hours has been used but most applications in which the silicate was dried utilized baking temperatures of 750 to 1475 degrees F for one-half to 8 hours. Some moisture remained in sodium silicate unless heated to above 360 degrees C (700 degrees F). Collins[22] used magnesium carbonate in the mold batch to set the silicate by changing the pH of the system. With 0.5 percent of $MgCO_3$ present, gel time at 9 degrees F was about 45 minutes. Lime ($CaCO_3$) has been used in a similar fashion.

More recently most investigators have employd carbon dioxide gas to gel the silicate and form a rapid bond. The reaction between sodium silicate and carbon dioxide is as follows:

$$Na_2O \cdot X\,SiO_2 \cdot H_2O + CO_2 \longrightarrow Na_2CO_3 + X\,SiO_2 \cdot Y\,H_2O$$

Silica gel ($X\,SiO_2 \cdot Y\,H_2O$) forms when any acidic materials are mixed with sodium silicate. In the mold it is the gel structure which bonds the silica grains together. This reaction is not reversible and therefore, once the mold is set, it cannot be softened again.

The application of CO_2 into the mold has been engineered in several ways. The hardening has been performed by exposing the mold to a quiet CO_2 atmosphere in an open vessel, by spraying the CO_2 from a nozzle over the surface and by forcing the CO_2 gas through the mold. A German process [13] involved the formation of passages in the mold about ⅜ inch in diameter and 8 to 12 inches apart. The gas at 1 to 3 atmospheres of gage pressure was then passed into these passages for from 20 to 40 seconds to produce adequate curing. Steck [19] reported a simple method of punching vent holes in the sand at about 5 inch intervals, inserting a tube at each vent hole and introducing the CO_2 through the tubes. He also suggested the use of vent holes in the sand mass, then covering the flask with a piece of plywood which was separated from the mold by a rubber gasket. The CO_2 was then blown through a hole in the center of the plywood. As an estimation of the cost of this treatment, Jansen [13] reported that about 2 percent of the CO_2 was required (probably percent by weight based on the sand).

Properties of Sodium Silicate Bonded Molds

Sysoev [17] reported that molds containing 40-50 parts by weight new sand, 40-50 parts used molding sand, 6-8 parts "semi-rich" sand with medium clay content and 4-8 parts waterglass, mulled for 6 to 10 minutes and cured with CO_2 had a permeability of 180-300, a compressive strength of 3.5 to 5.7 p.s.i. and a moisture content of 4-6 percent. Potocki [11] used 5 weight percent of sodium silicate of specific gravity of 1.35 and SiO_2:Na_2O ratio of 2.82:1. The test results indicated a green permeability of 150-170, a compressive strength of 0.74-1.2 p.s.i. and a moisture content of 4.0-4.5 percent. After injection of CO_2 for 10 to 20 seconds, the compressive strength was 206 p.s.i. and the permeability was unchanged.

Steck [19] discussed the properties of sodium silicate molds rather fully. He stated that molds made by this process were much more permeable than those made with normal foundry mixtures. Because of this and the moisture in the gel structure, metal penetration became a problem. He presented the example of a 2-inch square core made with AFS 50 sand, 17.4 percent of silica flour and 7.5 percent of waterglass which was coated with a silica wash. When cast in a 12-inch cube of steel with a riser 24 inches high, the core was completely penetrated. Further experiments along the same line were described as follows:

> "Two standard SFSA mold surface test blocks were made—one coated with a silica wash and the other uncoated. The surface of the casting made without wash had a very rough surface and the V-notch was completely penetrated. The casting made with the wash had a very good surface and the V-notch was free from penetrated sand. An iron oxide addition of about three percent improved the casting surface and minimized penetration. The iron oxide apparently fused and forms a viscous liquid barrier against metal penetration."

Steck further stated that the spalling resistance of the silicate bonded molds proved to be excellent and that less hot tearing occurred in these molds than in conventional molds.

Schumacher [18] made silicate bonded molds with about 5 percent of waterglass for cast iron castings at least as large as 330 pounds. His comments stated that the molds were more precise and had better surfaces than previous mold processes achieved.

Summary of Reported Advantages and Disadvantages of the Sodium-Carbon Dioxide Process

Advantages . . . The advantages to the sodium silicate-carbon dioxide process of forming metal casting molds cited in the literature may be summarized as follows:

1—Excellent dimensional accuracy was obtained when molds were hardened in situ.

2—Less floor space was required due to the more rapid cure time.

3—Castings appeared to be less susceptible to hot tearing.

4—Lower frequency of sand defects was encountered.

5—Foundry atmosphere was improved due to lack of or decrease in organics in the molds.

6—Drying and, hence, drying costs were eliminated.

7—The mold material and process could be adopted for mechanical forming without undue modification of equipment.

8—These mold compositions could be used successfully as facing sand with loose sand back up or could be employed without flasks.

Disadvantages . . . The following possible disadvantages have been stated in the literature:

1—The storage life of sand mixes was short.

2—Patterns must have generous taper and be free of dents or undercuts.

3—Some precautions were necessary in handling carbon dioxide requiring tank valves, in some cases, to be heated.

4—Sand reclamation must be by a wet process.

5—Pattern materials or surface coatings must be changed to avoid sticking of the mold material.

From an overall picture of the literature the consensus was that at least for a majority of applications the sodium silicate bonded casting mold could offer real advantages in reduction in cost and improvement of product with no very serious drawbacks. The only dissention to this opinion was Magens [14] who disagreed with nearly all the advantages stated above.

The Use of Sodium Silicate as a Binder in Cores

In the course of collecting the above literature on the production of molds bonded with sodium silicate, considerable information was accumulated on core compositions containing sodium silicate.

Many of the references cited above in the mold section also included data concerning core manufacture. Particularly references 13, 15, 16, 17, 18, and 19 related in considerable detail, production processes for silicate bonded cores. The patent literature specifically related to core making by this process is listed in Part B of the attached Bibliography.

The composition of core sands differed somewhat from that recommended for mold making due primarily to the need for somewhat greater strength in the core accompanied by the property of easy knock-out. Jansen [15] suggested that the quantity of sodium silicate used be proportional to the wall thickness of the casting with concentrations of 5 to 6 percent for cores for thick walled castings down to 3.25 percent for cores for castings with walls about ⅜ inch in thickness. He claimed that this proportioning, with the addition of 0.5 percent of asphalt binder, produced cores which collapsed from the heat of casting, removing the danger of cracked castings and making knock-out easy. These cores were cured by exposure to carbon dioxide. Wallace [27] patented a core binder made by boiling 90 percent of sodium silicate (SiO_2/Na_2O = 1.58, 41-42° Be′ solution) with 10 percent of solid sodium hydroxide until a clear solution was obtained. He then added 2.5 percent of NaOH and boiled again until a specific gravity of 52-54° Be′ was reached. This solution was diluted with 30 percent of water and one part of this added to 20 to 60 parts of sand. Cores were baked at 220 to 260 degrees C (420 to 500 degrees F). Ruddle [23, 24, 25] included aluminum sulphate and an alkali fluosilicate with the sodium silicate and a bitumen emulsion in core bond compositions baked at 350 to 500 degrees F. It was stated that cores made in this manner would, after casting, pour out of the casting as a finely divided granular material after only slight jarring. It appeared from these references that the foundries in this country which have investigated sodium silicate as a core binder generally cured by baking whereas the European investigators primarily depended upon carbon dioxide for curing bonds.

No radical changes from standard operating practices appeared to be necessary with sodium silicate bonded cores. Several instances were cited of the successful use of automatic core blowing machines [15, 16, 18]. Size did not seem to be of great importance since the same literature described small cores made in gang molds as well as cores weighing as much as 3.5 tons for a 4 ton casting. With CO_2, the hardening time for the latter core was about 15 minutes.

Reported Advantages and Disadvantages of Silicate Bonded Cores

The advantages attributed to baking cores with silicate bonds were of better dimensional accuracy and easier knock-out than with standard green sand molds. Along with these advantages, cores produced by the silicate-carbon dioxide processed added the economic advantages of almost instantaneous curing, elimination of baking ovens and baking time, and therefore, lower cost of production. Schumacher [18] estimated the cost savings to be at least 20 percent while Janseon [15] set the savings at $1.33 per net ton of sand processed. The disadvantages cited were the

(continued on page 14)

Figure 1 — An Example of Intergranular Fracture in Cast Armor Plate x1.

INTERGRANULAR FRACTURE IN STEEL CASTINGS

The British Steel Castings Research Association has issued a Report on the causes of intergranular fracture in steel castings and a means of eliminating it in foundry practice. The following is a digest of this investigation into the occurrence of intergranular (or rock candy) fracture in commercial and experimental steel castings.

PART I—Introduction

It has been observed in many foundries that a peculiar form of fracture occurs in both plain carbon and low-alloy steel castings which has the general appearance shown in Figure 1. This type of fracture is loosely referred to as "intergranular" fracture and is similar to what has been described in the United States as "rock candy" fracture. (see Figure 2).

Intergranular and Transgranular Fracture . . . Fracture must occur in polycrystalline metal either through the crystal grains or around the grain boundaries. The former type includes fibrous fracture, shear fracture, etc. and is called a trans- or intragranular fracture; the latter type embraces brittle forms of fracture and is called an intergranular fracture.

In the general case, the type of fracture shown by a given steel depends upon its microstructure, its previous strain history, and the condition of stressing, i.e., strain rate, stress system and temperature of testing. Thus the type of fracture shown by a steel in the tensile test can be changed by varying the microstructure, or for a given structure, by varying the temperature of testing. Similarly, the type of fracture may be altered if, for a particular microstructure and temperature of testing, the stress system or the strain rate is varied.

Nitrogen and Aluminum in Steel . . . Nitrogen is present in all commercial steels in amounts which depend upon the method of manufacture and the alloying elements present. Open-hearth steels usually contain nitrogen in the range of 0.003 percent to 0.006 percent, electric arc furnace steel from 0.006 percent to 0.012 percent and in high chromium ferritic steels the nitrogen content may be as high as 0.10 percent while in some austentic steels it may reach 0.30 percent.

The solubility of nitrogen in iron varies as the square root of the pressure. This implies that diatomic nitrogen gas dissolves as atomic nitrogen. The solubility of nitrogen in iron under one atmosphere is shown in Figure 3.

Nitrogen is an interstitial element in iron and has a strong tendency to form nitrides both with iron and with alloying elements. The following is a list of the nitrides which may be present in carbon and alloy steels: Fe_4N, Fe_3N, Fe_2N, Mn_4N, Mn_5N_2, Mn_2N, Mn_3N_2, Si_3N_4, AlN, Ni_3N_2, Ni_3N, Cr_2N, CrN, Mo_2N, MoN, TiN, ZrN, V_3N, VN.

It is generally believed that microscopically invisible nitrides occur in many steels and it is considered that these can have important effects on the properties of such steels. Many of the alloy nitrides are not only more stable than the nitrides of iron but

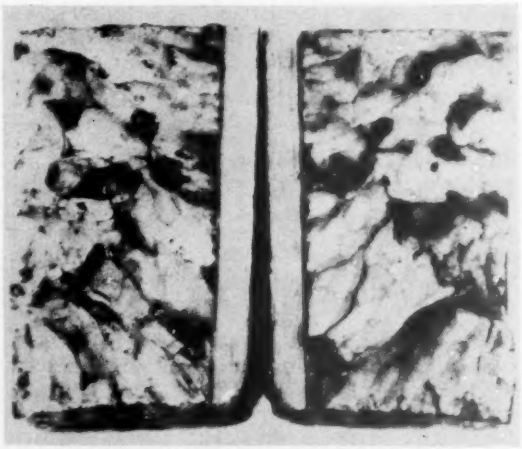
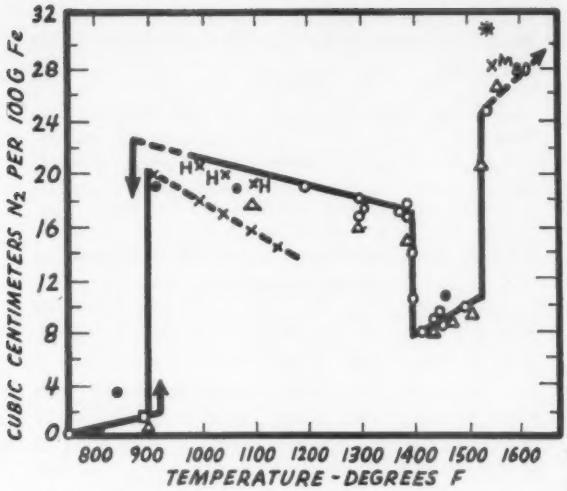


Figure 2—Intergranular Fracture in Castings Caused by Aluminum Nitride x1½



○ Zaph — 50 Gm. — Iron — Rising Temperature

● Zaph — 50 Gm. — Armco Iron — Falling Temperature

△ Zaph — 90 Gm. — Armco Iron — Rising Temperature

XXX Old Curve for Gamma Iron

X Hagen

✻ Chipman

Figure 3—Solubility of Nitrogen in Iron.

also have extremely low solubility in ferrite. The order of stability of the nitrides at 2730 degrees F. appears to be ZrN, TiN, AlN, BN, Si_3N_4, VN, Cr_2N, CrN and Fe_4N.

The nitrides formed by both zirconium and titanium are not only the most stable but also have an extremely low solubility in austenite and ferrite. These two elements, therefore, are regarded as combining with nearly all the nitrogen in steels to which they are added.

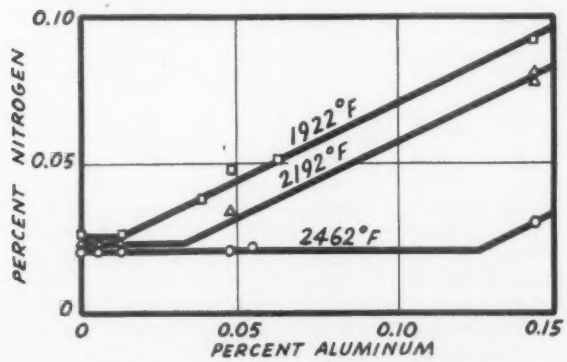


Figure 4—Nitrogen Content of Aluminum-killed Steels Equilibrated with Nitrogen Gas. (3)

Aluminum is believed to form only one nitride in steel, AlN. The curves in Figure 4 show the nitrogen content of aluminum-killed steels which have been nitrided.

By using the solubility product obtained for aluminium nitride it was possible to draw the series of curves in Figure 5. Any point on a curve represents the minimum aluminium and nitrogen contents that will produce saturation and just start to precipitate aluminum nitride at that temperature.

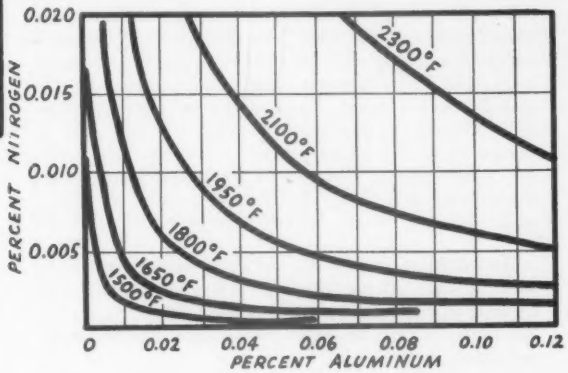


Figure 5—Minimum Aluminum and Nitrogen Contents to give a Precipitate of Aluminum Nitride at Various Temperatures.

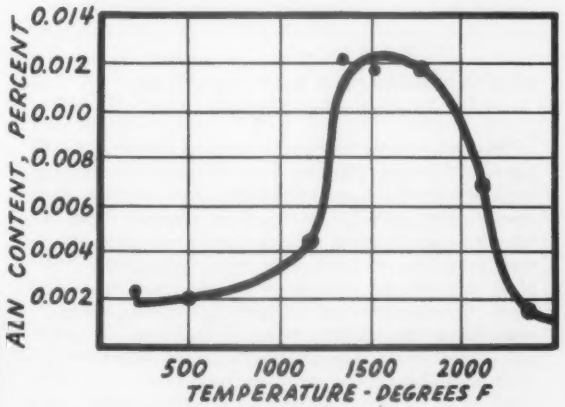


Figure 6—Variation of Ester-halogen Nitrogen Content of Steel Heated one hour at different temperatures. (4)

Beeghly[4], by using the ester-halogen separation method, has shown that the nitrogen present as aluminum nitride varies with the heat treatment, as shown in Figure 6. This curve may be regarded as providing some indication of the temperature variation of the solubility of aluminum nitride in the particular steel under study.

Acid soluble nitrogen . . . This embraces the nitrogen compounds decomposed either by dilute acid or by distillation in caustic soda solution. The acid soluble nitrogen in steel is present as solid solution in the ferrite or as one of the nitrides of iron, manganese, aluminum, zirconium, molybdenum, nickel or chromium (Cr_2N not CrN).

Ester-halogen Nitrogen

The ester-halogen nitrogen compounds are separated from the steel by solution in a mixture of bromine and methyl acetate and decomposed by distillation with caustic soda. The ester-halogen nitrogen content includes only aluminum nitride, zirconium nitride, and the nitrogen compounds present in silicon deoxidized steel. Even in the presence of titanium, silicon, or zirconium nitrides it is possible to determine the nitrogen present as aluminum nitride. The ester-halogen nitrogen in most aluminum deoxidized steels will be almost entirely present as aluminum nitride.

The difference between the ester-halogen nitrogen and the acid-soluble nitrogen will give the nitrogen present in the steel in solid solution in the ferrite or combined with the iron, manganese, molybdenum or nickel.

Total nitrogen . . . This represents the nitrogen present in steel in all forms. The difference between the soluble and total nitrogen results gives the amount of nitrogen combined as one or more of the insoluble nitrides, namely, TiN, BN, VN, CrN.

PART II—Commercial Heats Exhibiting Intergranular Fracture

Specimens from twelve commercial steels in which intergranular fracture had been found were supplied by member firms of the British Steel Castings Research Association for examination. Details concerning the manufacture and properties of these steels were given but are omitted in this digest as the complete deoxidation practice was not given in many cases. It appeared that all steels but one were aluminum killed; the amount varied from 1 to 2 pounds per ton of steel. The compositions of the steels are given in Table I.

Analytical Results on Nitrogen Content of Commercial Steels

Most of the steels were analyzed for acid-soluble nitrogen, ester-halogen nitrogen, total nitrogen and acid-soluble aluminum. The results are given in Table II.

The acid-soluble nitrogen contents found in the commercial steels range from 0.00444 percent for steel G to 0.0103 percent for steel L. Table II shows that the ester-halogen nitrogen content of most of the steels is slightly less than the acid soluble nitrogen values.

A rather surprising feature of the analytical results for the commercial steels was the high aluminum figures obtained. With the exception of E all the aluminum contents were greater than 0.1 percent

TABLE I—Composition % of the Commercial Steel Examined

Steel	C	Mn	Si	S	P	Ni	Cr	Mo
A	0.24	1.38	0.48	0.029	0.039	.....	.....	.....
B	0.35	1.46	0.38	0.019	0.026	0.84	0.61	0.35
C	0.35	0.83	0.47	0.014	0.024	.....	.....	.....
D	0.23	0.69	0.46	0.019	0.029	.....	.....	.....
E	0.30	0.81	0.32	0.015	0.041	.....	.....	.....
F	0.31	1.38	0.40	0.025	0.012	0.73	0.42	0.36
G	0.30	0.50	0.29	0.008	0.021	2.42	0.58	0.39
H	0.27	1.5	0.38	0.016	0.030	0.70	0.62	0.32
J	0.12	0.36	0.30	0.010	0.015	3.93	1.47	0.02
K	0.05	0.40	0.24	0.008	0.004	4.07	1.48	0.05
L	0.24	1.2	0.25	0.05	0.05	.....	.....	.....
	0.29	1.7	0.50	max.	max.	.....	.....	.....

TABLE II—Analytical Results on Commercial Steels

Steel	Acid-Soluble N%	Ester-Halogen N%	Total N%	Acid-Soluble Al%	Intergranular Fracture %
A	0.0080	0.0095	0.0110	0.17	0
				x	
	0.0083	0.0093	.....	0.17	.....
B	0.0091	0.0077	0.0091	0.23	80
	0.0085	0.0080	.....	.....	.....
	0.0080	.....	.....	.....	.....
	0.0079	.....	.....	.....	.....
C	0.0093	0.0075	.....	0.24	.....
	0.0105	.....	.....	0.25	60
	.....	.....	.....	0.25	.....
D	0.0049	0.0059	0.0059	0.24	.....
	0.0046	.....	.....	0.24	50
E	0.0102	0.0093	.....	0.04	.....
	0.0095	.....	.....	.....	.....
F	0.0070	0.0062	.....	0.15	45
	0.0061	.....	.....	.....	.....
G	0.0046	0.0051	0.0088	0.12	.....
	0.0042	.....	0.0072	0.13	25
H	0.0083	0.0046	.....	.....	.....
	0.0073	.....	.....	.....	25
J	0.0065	0.0051	0.0097	0.09	100
K	0.0042	0.0063	0.0091	0.08	100
L	0.0108	0.0087	.....	0.16	.....
	0.0098	.....	.....	.....	.....

and many were greater than 0.2 percent. In the experimental melts, the mold additions of aluminum at the rate of 2 pounds per ton of steel made to series F gave a final aluminum content of about 0.06 percent while in series B an aluminum addition equivalent to 1 pound per ton of steel resulted in a final aluminum content of about 0.5 percent.

Although aluminum losses may not be the same in commercial and experimental melts, an addition of 1 pound of aluminum per ton of steel is theoretically equivalent to 0.0045 percent aluminum, so with an addition at the rate of 2 pounds of aluminum per ton of steel, the aluminum remaining in the steel should not exceed 0.09 - 0.10 percent. On this basis most of the commercial steels would seem to have had additions of from 3 to 5 pounds of aluminum per ton of steel rather than the amounts actually reported which were of the order of 2 pounds or less.

Fractography of Commercial Steels

The fractographic examination of each of the commercial steels was made on specimens which had been quenched and tempered at 1200 degrees F. for one hour after which they were water quenched to avoid temper brittleness. The pieces were then notched and fractured by slow bending in a tensile testing machine. The results obtained are given in the last column of Table II.

The only steel which did not contain intergranular fracture when tested in the quenched and tempered condition was steel A and only steels J and K gave complete intergranular fracture.

Two Charpy specimens from Steel B were broken at + 68 degrees F and at −297 degrees F. The specimen at 68 degrees F. contained 60 percent intergranular and 40 percent fibrous fracture and the specimen broken at −297 degrees F. was only 5 percent intergranular fracture and 95 percent brittle cleavage fracture. Thus it can be seen that with decreasing temperature of testing the resistance to fracture of the grains falls below that of the grain interfaces and so transgranular fracture replaces intergranular over most of the specimen.

The fact that steel A does not show any intergranular fracture is significant because it was observed that the original fracture followed the ferrite grain boundaries present in the structure. The original fracture surface was heavily oxidized which indicated that failure occurred either on cooling after solidification, or at room temperature and the oxidation took place during subsequent heat treatment. Thus the intergranular fracture in steel A was caused by the presence of ferrite films around either austenite or pearlite grains together with the development of a high internal stress system at certain points in the casting.

It was observed the general appearance of all fractures (except G) were the same but it does not necessarily follow that all fractures were due to the same cause.

Metallography of the Commercial Steels

Microspecimens were carefully prepared and examined both unetched and after etching in each of several reagents, e.g., nital, picral, villela's reagent, aqueous picric acid. In the majority of cases no grain boundry precipitates could be found in the commercial steels. The exceptions were steels D, E, J and K. Although considerable time was spent in attempting to detect grain boundry phases, no success was achieved for the other steels.

Effect of Heat Treatment on the Occurrence of Intergranular Fracture

The commercial steels, B and K were subjected to heat-treatment. The preliminary treatments made it clear that temperature of 1470 to 1750 degrees F. had little or no effect in removing the intergranular weakness.

It was found that treatments at temperatures up to 2000 degrees F. had no effect on the occurrence of intergranular fracture even if the time of treatment was prolonged. However, at temperatures of 2000 degrees F. and 2100 degrees F. there was some indication that the intergranular weakness was being reduced by prolonged holding. The examination of specimens treated at 2190 degrees F. indicated that some reduction in the amount of intergranular fracture was occurring, but at least 50 percent intergranular fracture was still present after 5 hours. The specimens which were oil quenched from 2280 degrees F. did not show any intergranular fracture either after tempering at 1100 degrees F. or after oil quenching from 1650 degrees F. and tempering at 1100 degrees F.

Several specimens of steel B were heated to 2280 degrees F. and held for 2 hours after which one was removed and oil quenched to check that intergranular fracture had been removed. The remaining specimens were cooled in the furnace and the specimens were removed and oil quenched at 2200 degrees F., 2000 degrees F. and 1300 degrees F.; one specimen was cooled to room temperature in the furnace. All specimens were then oil quenched from 1650 degrees F. and tempered at 1100 degrees F. before being fractured.

The specimens quenched from 2280, 2200 and 2000 degrees F. did not show any intergranular fracture but the specimens that were cooled to 1300 degrees F. and room temperature did exhibit intergranular fracture.

When specimens were heat treated in an argon atmosphere furnace, intergranular fracture was present in quenched and tempered specimens after treatments up to one hour at 2280 degrees F., but was absent from those specimens held for 1½ hours or longer. The development of intergranular fracture at temperatures below 2280 degrees F. depends upon both time and temperature.

The highest temperature at which intergranular weakness would develop was determined by heating a number of specimens at 2280 degrees F., cooled in the furnace to a desired temperature, held for an hour at that temperature and then oil quenched and tempered to 1200 degrees F. Various specimens were cooled in the furnace to temperatures of 1970, 2000, and 2085 degrees F. and the percentage of intergranular fracture was 60 percent, 50 percent and 5 percent respectively. Therefore, it appears that 2085 degrees F. is the highest temperature at which the conditions giving rise to intergranular fracture in steel B will develop. The lowest temperature at which intergranular weakness can develop is presumably believed to extend to 1470 degrees F. or lower.

A few heat treatments were carried out with the commercial steel K which responded in a different manner to steel B. The appearance of the intergranular fractures in steel B was not affected by heat treatments below 2280 degrees F. In the case of steel K heating at 1650 degrees F. caused the intergranular facets in the quenched and tempered specimen to become much duller; therefore, it seems that partial removal of the intergranular weakness of steel K occurs at 1650 degrees F. Treatments at 2280 degrees F. for 2 hours entirely removed the intergranular fracture, and specimens furnace-cooled from this temperature were completely free from this form of failure.

Parts III and IV Experimental Heats and Prevention of Intergranular Fracture will be published in the next issue of the Journal.

The Use of Sodium Silicate (continued from page 9)

same as described for the use of the process for mold making.

No health hazards had been found with the use of this process [18]; however, strongly alkaline sodium silicate might cause dermatitis in susceptible persons [19].

Conclusions

Soluble silicates have been employed successfully on a commercial scale in the fabrication of metal casting molds and cores. The major advantages appear to lie in more rapid production and in fewer sand defects. Although certain changes seem to be necessary in standard foundry procedures, no major difficulties have been encountered in the process. It is believed, based on this search and preliminary experimental work, that the previous use has been with silicate concentration considerably higher than should be necessary and that organic additives could be entirely eliminated. From the present knowledge of the field, it would seem possible for the steel foundry to take advantage of the technical and economic advantages of this process on an immediate basis.

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Durability of Sands (continued from page 6)

It appears significant that scabbing in these tests occurs before the sand has been used ten times and thus it is possible to microscopically differentiate one used sand from any other in a series.

Examination of sand from three foundries has indicated that the appearance of used sand may be correlated with suitability for facing sand. For example, backing sand from Foundry F is similar to test sand after ten or twelve uses (very susceptible to scabbing). Sand from Foundry U is similar to the test sand after seven uses (on the verge of scabbing). Examination of reclaimed sands from Foundry W showed that: (1) good reclaimed sand, with a light meter value of 7, was similar to the test sands after two uses (good sand); (2) poor reclaimed sand, with a light meter value of 5.8, was similar to the test sands after six uses (on the verge of scabbing); and (3) very poor by reclaimed sand, with a light meter value of 4.3, was similar to test sands after eight uses (susceptible to scabbing). At Foundry W, light meter values of reclaimed sand are used to control their reclamation process.

Summary of Results and Conclusions

1—No difference was detected in the scab-free life or durability of the three foundry sands most commonly used in Canada.

2—Durability of the test sands was a function of deterioration of the bond and not of the sand.

3—Analysis of results of individual sand tests at room temperature (Permeability, Green Compressive Strength, Green Shear Strength, Green Tensile Strength, Dry Bond Strength, Moisture Content, Green Deformation and pH) showed no correlation with deterioration of the test sand mixes.

4—Properties at elevated temperature, particularly hot compressive strength and resistance to thermal shock are factors which apparently influence susceptibility of sands to scabbing. The used sands develop relatively high hot compressive strengths and become very sensitive to thermal shock.

5—No correlation was apparent between unaccommodated expansion and susceptibility to scabbing.

6—Used sands, after thorough washing to remove live bond, were found to be coated with a very adherent magnetic shell of dead bentonite, carbon, and probably fayalite from casting peel.

7—Progressive deterioration of the sand mix may be observed by microscopic examination of the "cokey" coatings which build-up on the sand grains. In many cases, it should be possible to correlate the appearance of the coatings with the occurrence of defects for particular castings or types of castings.

8—The durability of the test sand mixes with respect to large drag scabs was not affected by mold hardness.

9—The durability of the test sand mixes with respect to small drag scabs was affected by mold hardness. The durability decreased with increased mold hardness.

10—Examination of the used sands suggests that deterioration resulted from a dilution of the live bond with contaminants (such as burned-out bentonite, burned-out cereal and crushed peel) and/or the formation of a very adherent foreign coating (shown to be non-colloidal, high in carbon content high in iron content and magnetic) which changes the effective bonding surface of the sand grains.

The studies of this report were initiated and directed by the Research Steering Committee of the Steel Castings Institute of Canada. The research was carried on at the Mines Branch of the Department of Mines and Technical Surveys, Canadian Government, Ottawa, Canada. The staff members of the Mines Branch are to be commended for their splendid cooperation.

NEW PROJECTS ON SAND

Research Project No. 45
Organic Bonding of
Steel Foundry Molding Sands

Scope . . . Recent studies on shell molding of cast steels have shown that the two-step phenol-formaldehyde resin can be successfully employed with silica sand to produce cores and molds. Urea-formaldehyde resins and one-step phenol-formaldehyde resins also can be used to bond sand for steel castings but they lack certain properties which the two-step resin possesses.

One particular disadvantage of resin binders is that they release enormous quantities of gas as the resin is dissociated by heat into hydrogen, methane, carbon dioxide, nitrogen and water vapor. The gas is released early, usually during the solification of the skin of the steel casting with impairment of the surface smoothness and lack of definition or sharp and precise casting contour.

There are organic compounds other than resins that may be effective as binders of silica sand. New compounds are being developed all the time. It is possible that some may be employed in liquid form which could result in reproduction of patterns and a set form without the application of heat.

The Technical Research Committee realizes that it has very little knowledge of the field of organic binders and, therefore, the Committee believed that it would be beneficial to work with a company that produced plastics, resins, and other organic compounds that might act as binders suitable for steel foundry application.

Objective . . . It is planned to study the properties and behaviors of potential organic bonds and to ascertain their effectiveness when bonded with molding sand in the production of steel castings.

Research Procedure . . . Organic materials (with or without a catalysis) that have any bonding possibilities will be listed and grouped as to possible effectiveness.

These materials will then be mixed with sand to determine their bonding possibilities and gas volume and type of gas at some feasible temperature. If acceptable molds are formed they will be further assigned to experimental studies with molten steel.

Molds of various designs will be made from the organic bond and poured with molten steel. Surface and internal characteristics of the castings will be examined and tolerances studied. Gas volume and composition will be determined on sand and bond samples surrounded by molten steel.

Organic bonds that show possibilities of production use will be given a semi-production test by making the Society surface finish test block and other appropriate castings.

Research Approach . . . The Technical Research Committee has asked the research staff of a chemical company to carry on the first phase of exploring the various organic compounds and the selecting of possible bonding materials. The means to test green compression and dry strengths are available as well as an oven for temperatures up to 500 degrees F.

A university laboratory will carry on the experimental studies with molten steel. The chemical laboratory will furnish the binder to the foundry laboratory and test molds poured with molten steel will be produced.

Bonding materials that have production possibilities will be passed along to a selected steel foundry for semi-production tests.

Estimate of Time and Cost of Research . . . A three-year program is required to carry on the research and test studies at a total cost of $32,250.00.